Design

Design for Welding

Lecture Scope

- Welding Design Considerations
  - advantages and disadvantages of welding
  - alternatives to welding
- Design of Welded Joints
  - joint types
  - weld types
  - joint preparation for welding

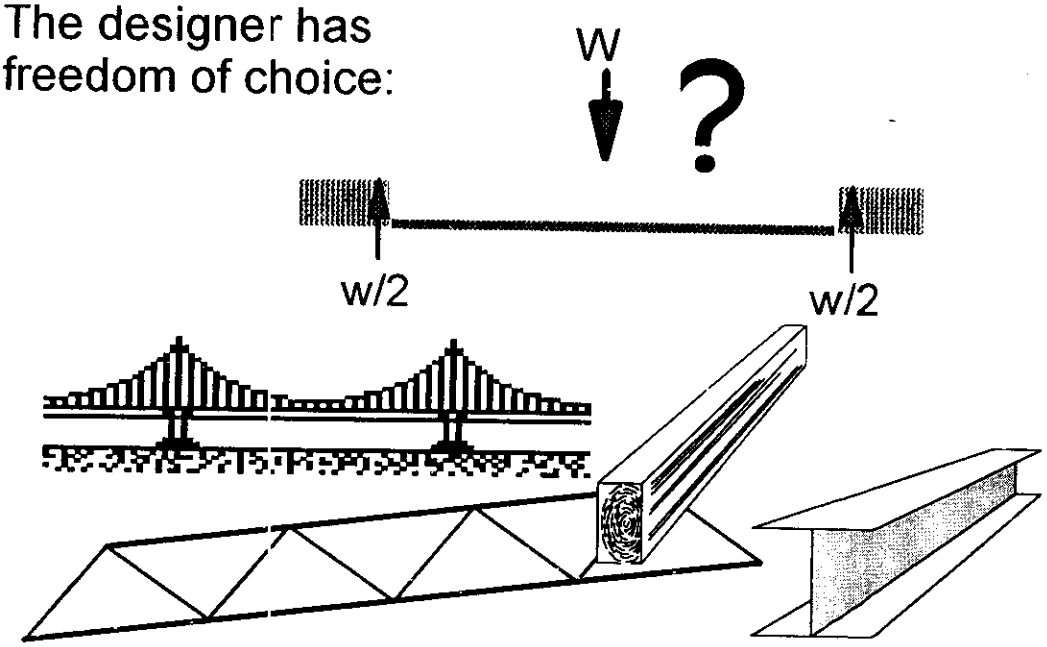
Design Considerations

The basic objectives of design are to define an assembly that

- will perform its intended functions safely and reliably
- can be constructed, inspected and maintained at the minimum total cost

Design Considerations

The designer has freedom of choice:



Design Considerations

- Loads
- Geometry
- Stiffness
- Methods of analysis
- Detail design
- Weight
- Appearance

- Costs
  - Design
  - Materials
  - Fabrication & Erection
  - Inspection
  - Operation
  - Maintenance & Repair

Competing Joining Methods

- Welding — pressure vessels, ships
- Brazing — CANDU fuel bundles
- Soldering — electronic assembly
- Bolting — steel trusses, machine parts
- Riveting — truck bodies, aircraft skins
- Adhesives — aircraft
- Integral construction
  - casting, forging, powder metallurgy, machining

Advantages of Welding

- Joint quality:
  - strength
  - rigidity
  - leak tightness
  - durability
  - resistant to service environment, temperature, corrosion, irradiation
- Cost
  - flexible options for design
  - low cost materials, processes
  - rapid assembly

Disadvantages of Welding

- affects material properties
  - strength, hardness, toughness, corrosion resistance
- distortion of precision assemblies
- residual stress
  - affects fracture, fatigue life
- heat damage to surface finishes or adjacent components
- may require skilled workers, high-cost equipment

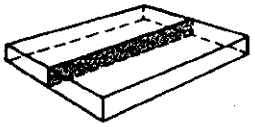
Selection of Joining Method

- Welding is never the only design solution
- Designers should select welding when
  - welding offers the most satisfactory joint quality (e.g. nuclear pressure vessels and piping)
  - welding is the lowest-cost production method (e.g. office furniture)

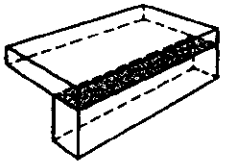
Design

Design of Welded Joints

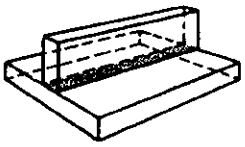
Joint Types



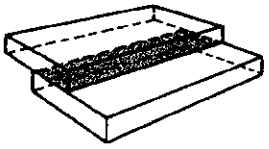
Butt joint



Corner joint



T Joint



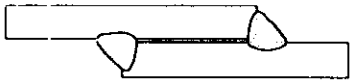
Lap Joint

Weld Types

- Fillet Welds
  - Consist of a triangular weld deposit joining two members approximately at right angles
- Groove Welds
  - Consist of weld metal deposited in a groove or bevel formed by the edges of the adjoining parts

Weld & Joint Arrangements

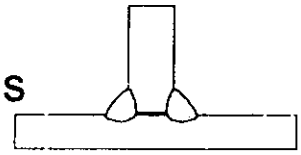
Common joint arrangements with fillet & groove welds



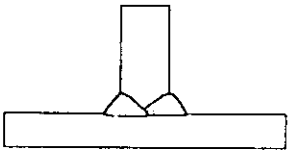
Lap Joint

Butt Joint

Fillet Welds

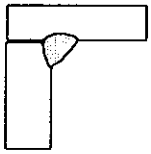


T Joint

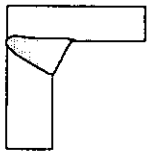


T Joint

Groove Welds

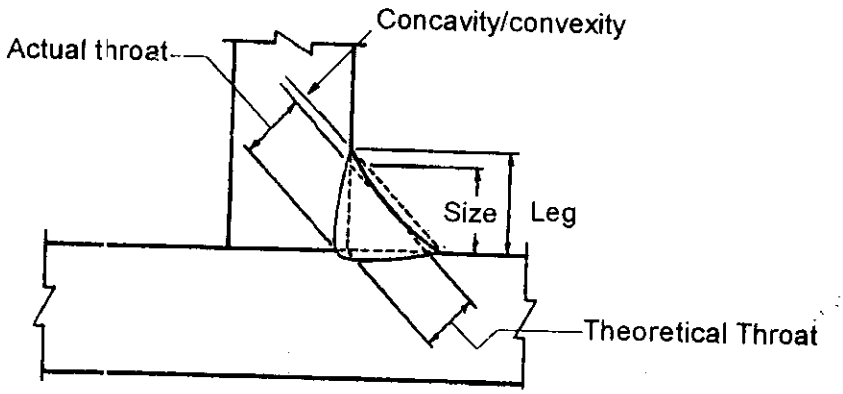


Corner Joint



Fillet Welds

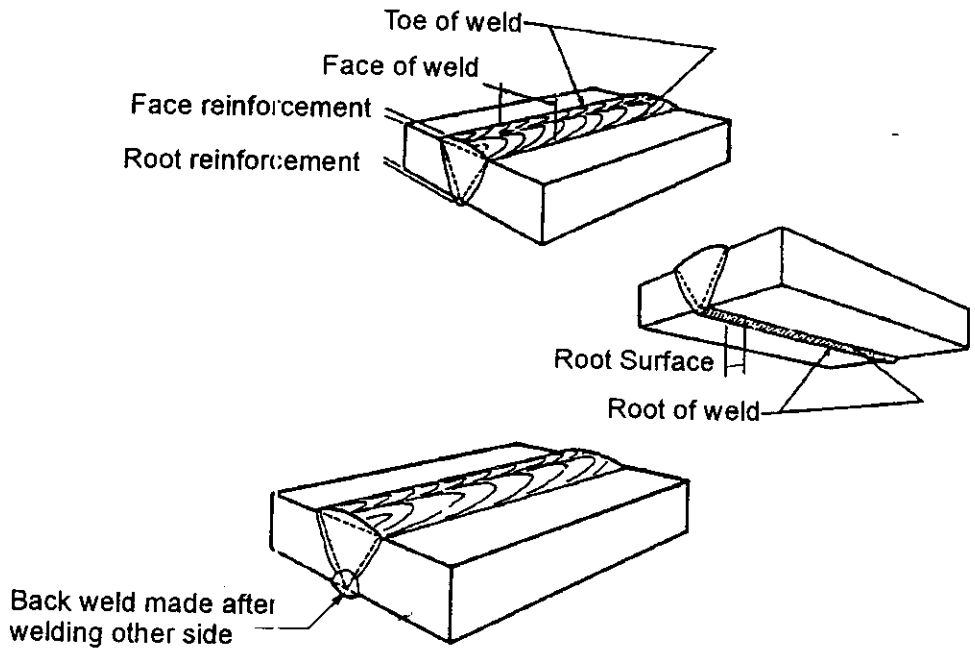
- Fillet weld size is defined as the side of the largest right angled equal leg triangle that can be drawn within the weld outline
- Weld throat is the height of the triangle = 0.7*size



Fillet Welds

- When the design permits, fillet welds are used in preference to groove welds for economy
- Used in lap, corner and T joints
- Simple to prepare and fit up

Groove Welds



Weld Penetration

- "Partial penetration" groove welds extend part way through the joint
- "Full penetration" welds fuse the entire thickness of the joint.

Groove Weld Joint Preparation

- "Square groove" welds are made by butting two sections with a gap if necessary to aid weld penetration
- The maximum thickness depends on the welding process:
  - from 4 mm with GTAW to about 15 mm with SAW
- In thicker sections, the joint edges must be bevelled to give access to the root, and the groove is filled in one or more passes.
  - The first pass is termed the "root" pass
  - Subsequent passes are known as the "fill" and "capping" passes

Groove weld root pass

- When both sides of the joint are accessible
  - a sealing pass can be deposited on the reverse side after surface preparation
  - A metal backing strip can be fitted across the bottom of the groove to support the weld pool during welding
  - A removable flux or non-fused backing may be used
- When the joint is accessible from one side only
  - Satisfactory penetration and root profile must be obtained as welded
  - Accurate joint preparation and fit-up is necessary
  - GTAW is often used for root pass because it permits good control of joint fusion

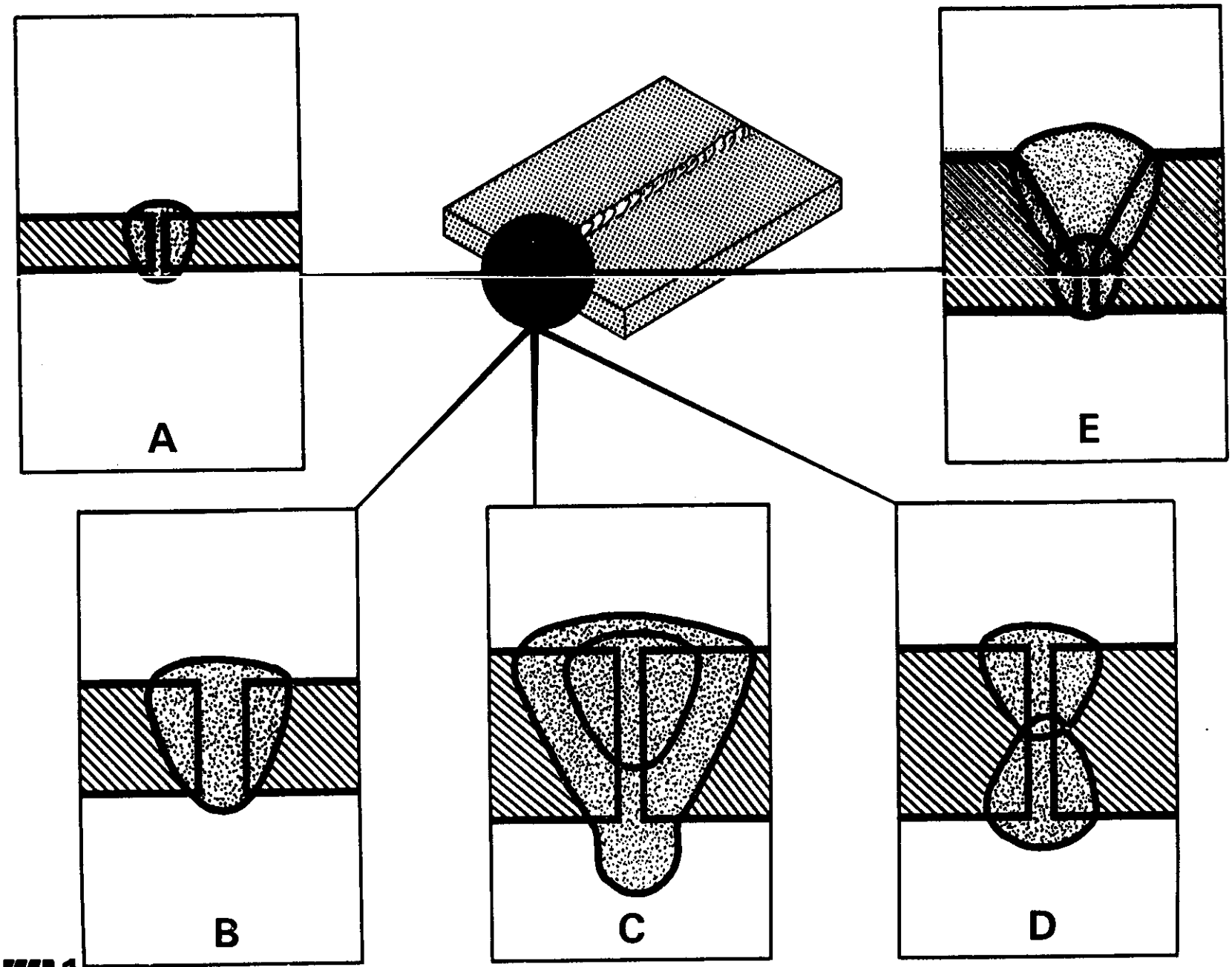
SET B

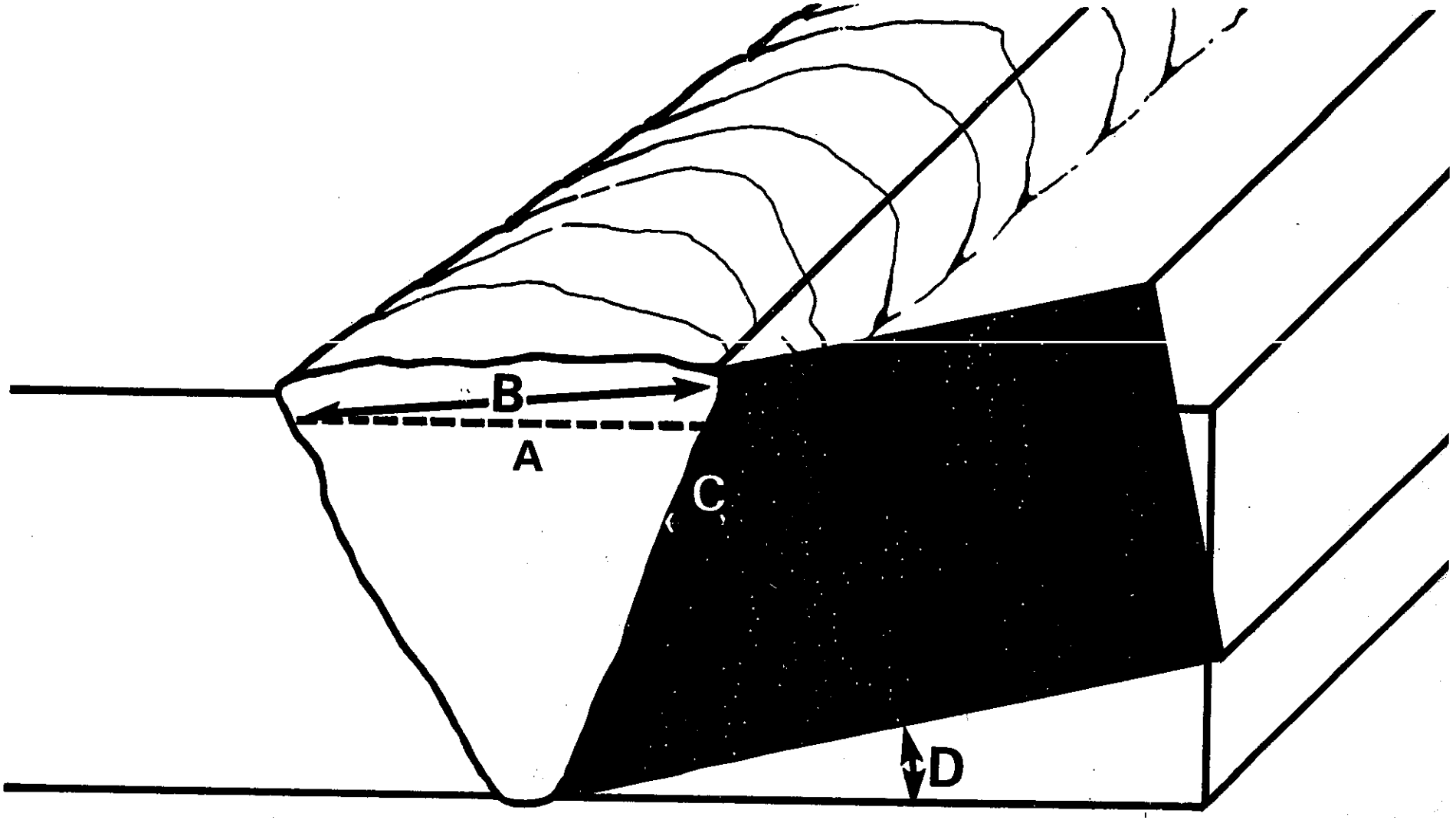
Section

1 THE NEED FOR EDGE PREPARATION: Obtaining full penetration with V-preparation.
2 DISTORTION OF SINGLE-V: Shrinkage on cooling.
3 OTHER EDGE PREPARATIONS: U, double-V, double-U, T-joints.
4 EDGE PREPARATION DIMENSIONS - BUTT JOINTS: Terminology, typical figures, remedial action.
5 EDGE PREPARATION DIMENSIONS - T-JOINT AND HORIZONTAL-VERTICAL BUTT JOINT: Terminology, typical figures, remedial action.
6 BACKING: Permanent, temporary, proprietary systems, integral.
7 CORNER AND ANGLE JOINTS: Inside and outside fillet welds, butt welds.
8 PIPE BUTT JOINTS: Single-V, single-U preparations, fusible inserts, horizontal-vertical weld.
9 PIPE BRANCH JOINTS - 90°: Set-on, set-in.
10 PIPE BRANCH JOINT - ANGLED: 45° set-on.
11 BACK GOUGING - APPLICATION: Removing partial penetration root run, square edge gouged to form J-preparation.
12 BACK GOUGING - METHODS: Oxy-gas, air-arc, grinding.
13 EDGE PREPARATION - METHODS: Milling, shaping, nibbler, gas cutting.
14 JOINT ASSEMBLY: Correct, misalignment, incorrect gap, tack welds, bridging piece, temporary attachments with wedges.
15 KEYHOLING: Cross-section of electron-beam weld, cut-away diagram of keyholing.

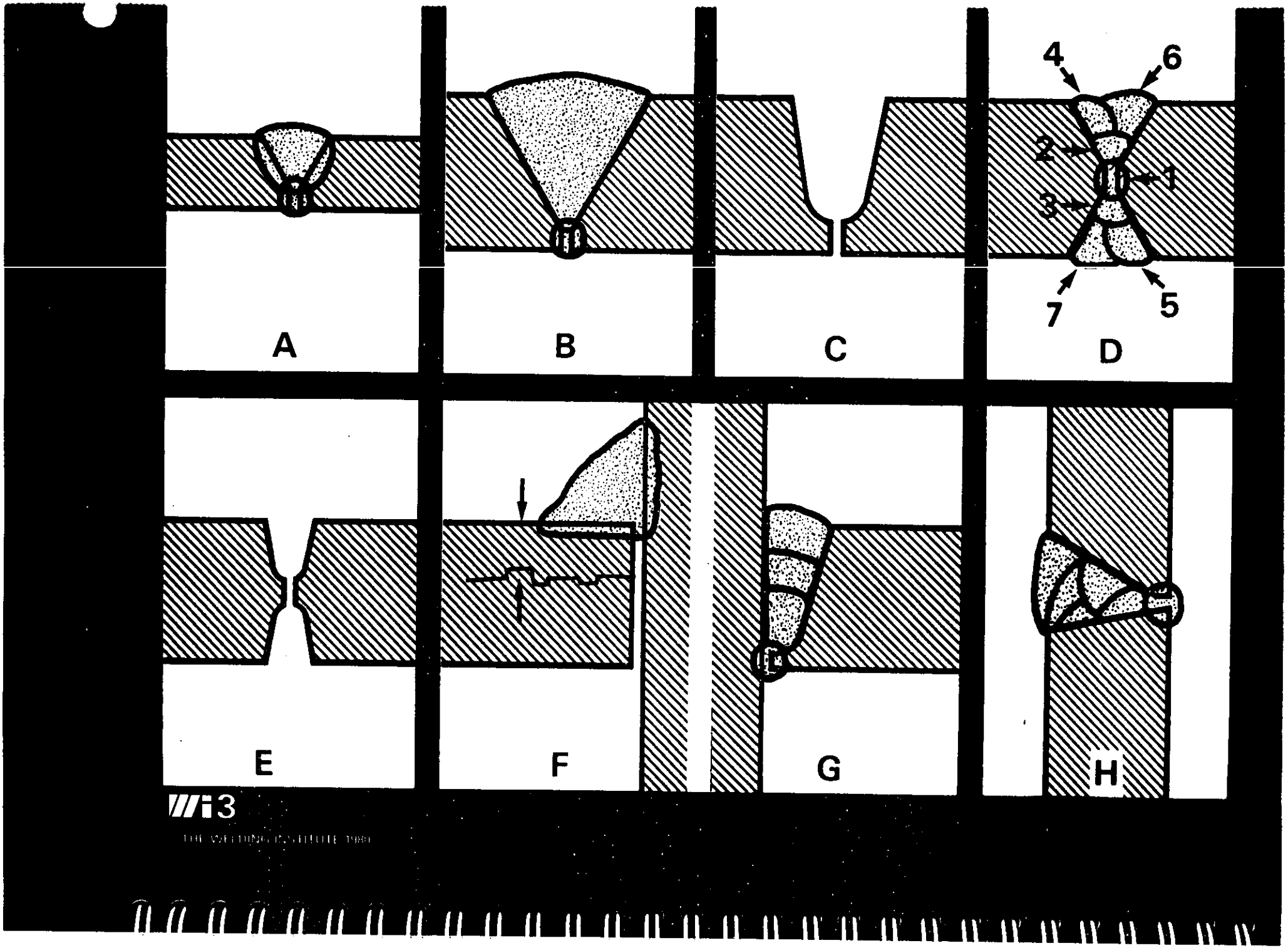
INTRODUCTION

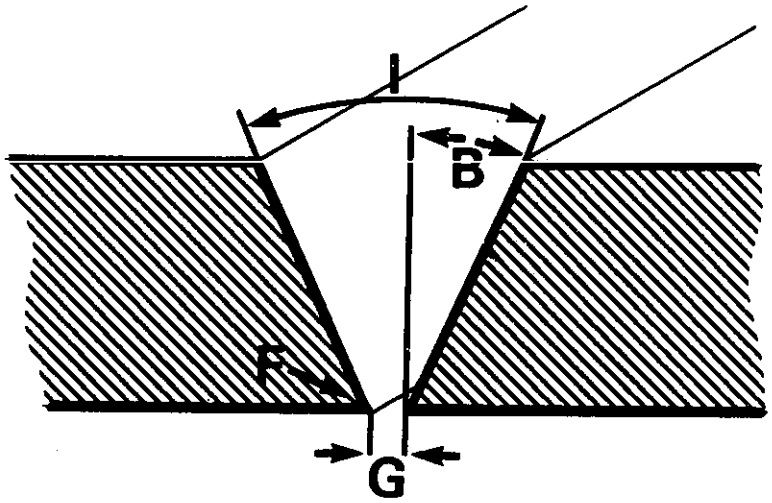
This set of transparencies covers the major points relevant to joint preparation. The main emphasis is on edge preparation for arc welding, and the aim is to show the principles behind the various edge preparations rather than simply list recommended procedures.
In industrial training, the lecturer will be able to relate this information to the procedure which the students will be using.

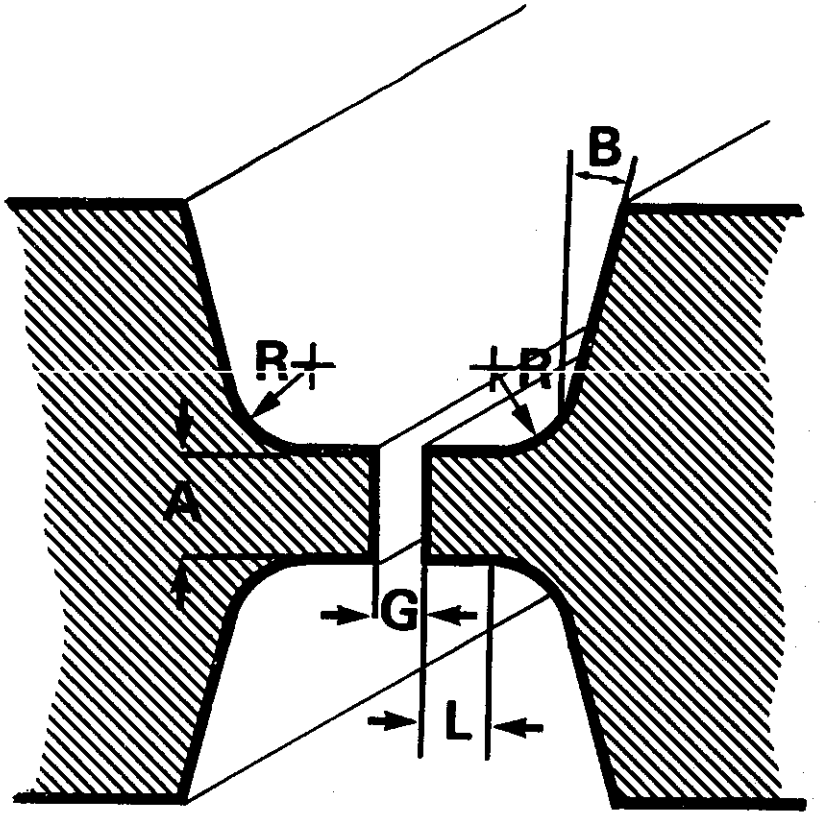




Wi 2a


4
6
2
1
3
7
5
A
B
C
D
E
F
G
H





TWI

SECTION 4 : EDGE PREPARATION DIMENSIONS — BUTT JOINTS

4 (Single transparency)

Note that the drawings are intended to show the terminology of the dimensions only, and do not represent an actual edge preparation.

Terminology (BS 499 Part I)

A	Root face	I	Included angle
B	Angle of bevel	L	Land
F	Feather edge (root face = 0)	R	Root radius
G	Gap		

Typical figures (mm and degrees)

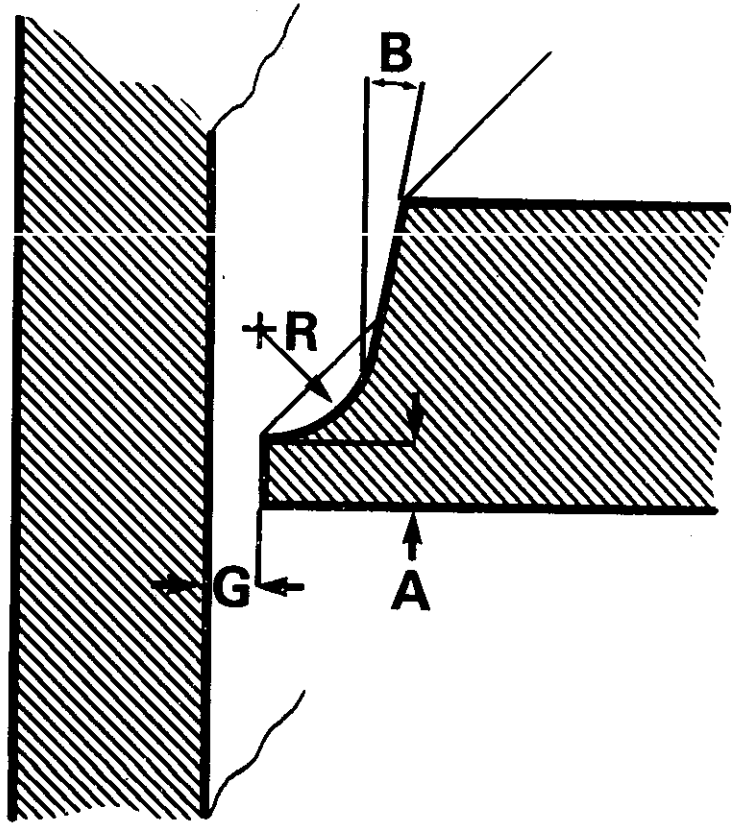
Section shown on		Left	Right	Right
Parent metal thickness		6-20	12-22	50
Position		Flat	Flat	Flat
Process		CO_2 1.2mm Solid wire	CO_2 Dip Transfer	CO_2 Mechanised
Root face	A	—	—	13
Angle of bevel	B	15	30	15
Gap	G	3△	1.5	0
Included angle	I	30	60	30
Land	L	—	—	0
Root radius	R	—	—	6
* 'Standard data..' table		145	—	—
* 'Joint preps..' page		—	23	23

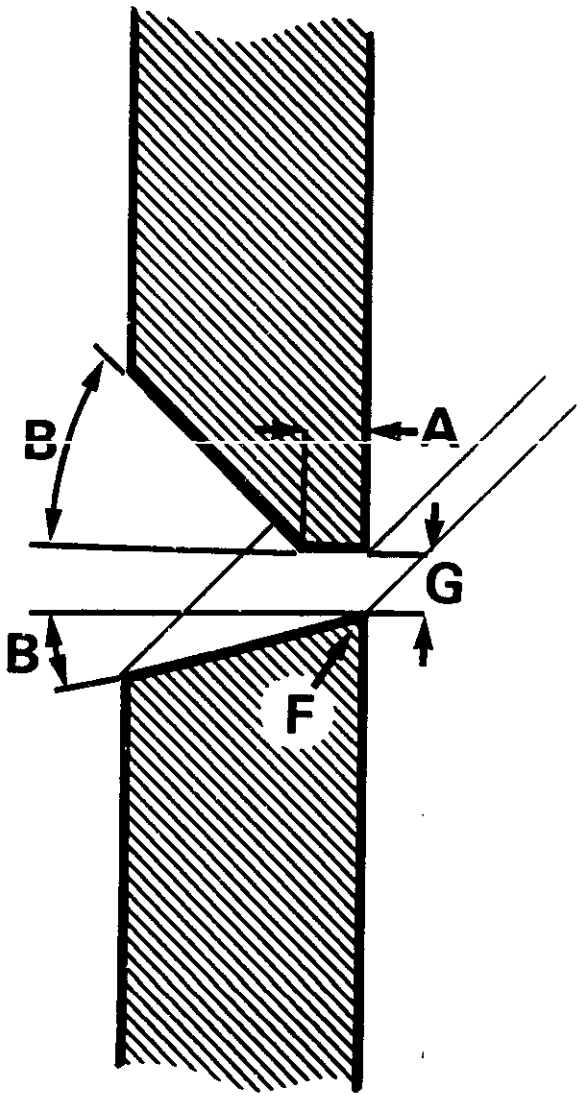
△ with backing strip — see Section 6

* location of data in the WI publications referred to in the introduction (1975/1976 editions)

Remedial action

Problem	Gap	Root face	Angle of bevel	Welding current
	(I-Increase : D-Decrease)			
Insufficient penetration	I	D	-	I
Excess penetration	D	I	-	D
Lack of fusion } Slag inclusions } (where due to restricted access)	I	D	I	I
Excess distortion	D	-	D	I
Slow welding	D	I	D	I





SECTION 5 : EDGE PREPARATION DIMENSIONS – T-JOINT, HORIZONTAL-VERTICAL BUTT JOINT

5 (Single transparency)

Terminology (BS 499 Part I)

A	Root Face	G	Gap
B	Angle of bevel	R	Root radius
F	Feather edge (root face = 0)		

Note that for the J preparation on the left, the angle of bevel is the same as the included angle.

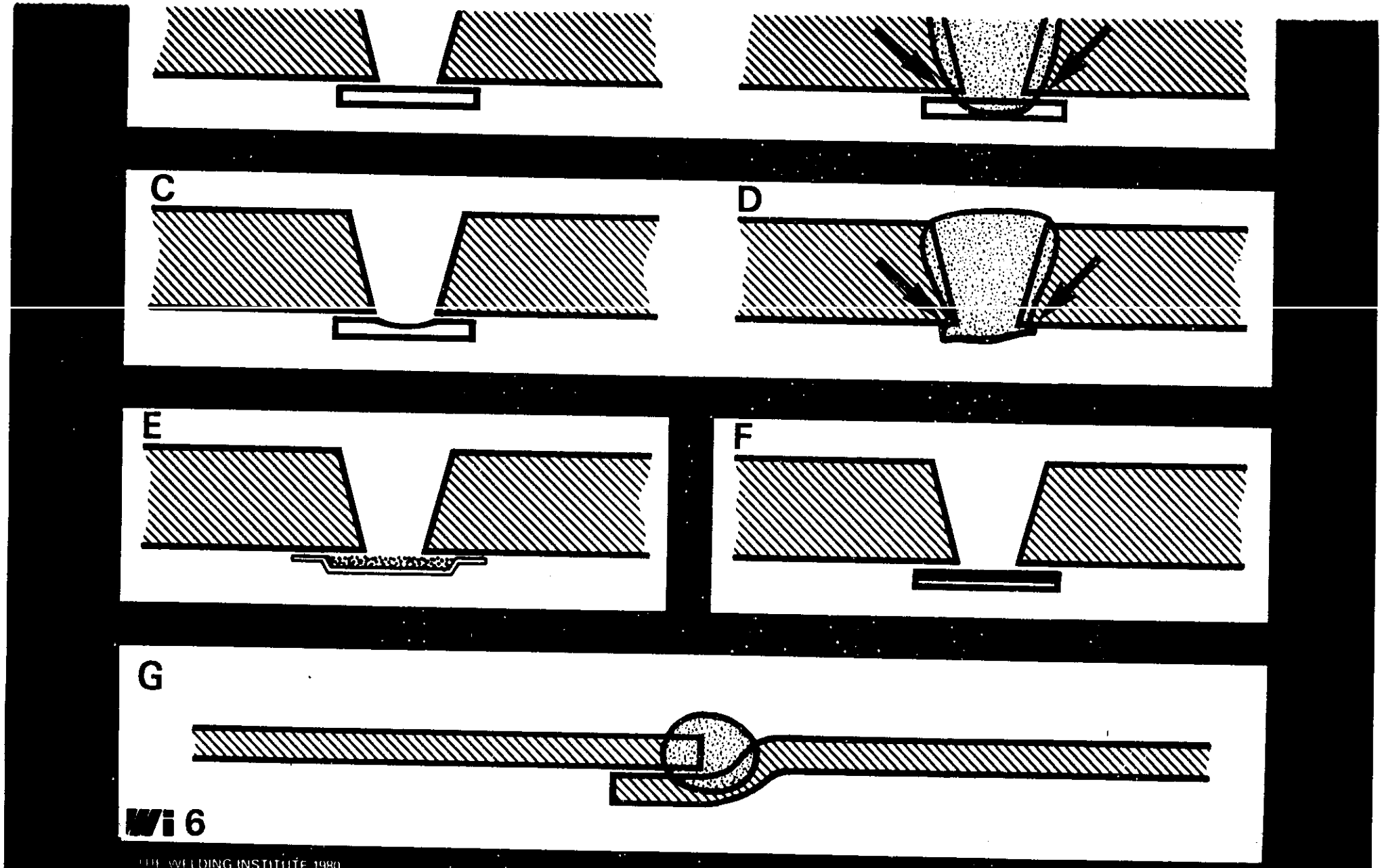
Typical figures (mm and degrees)

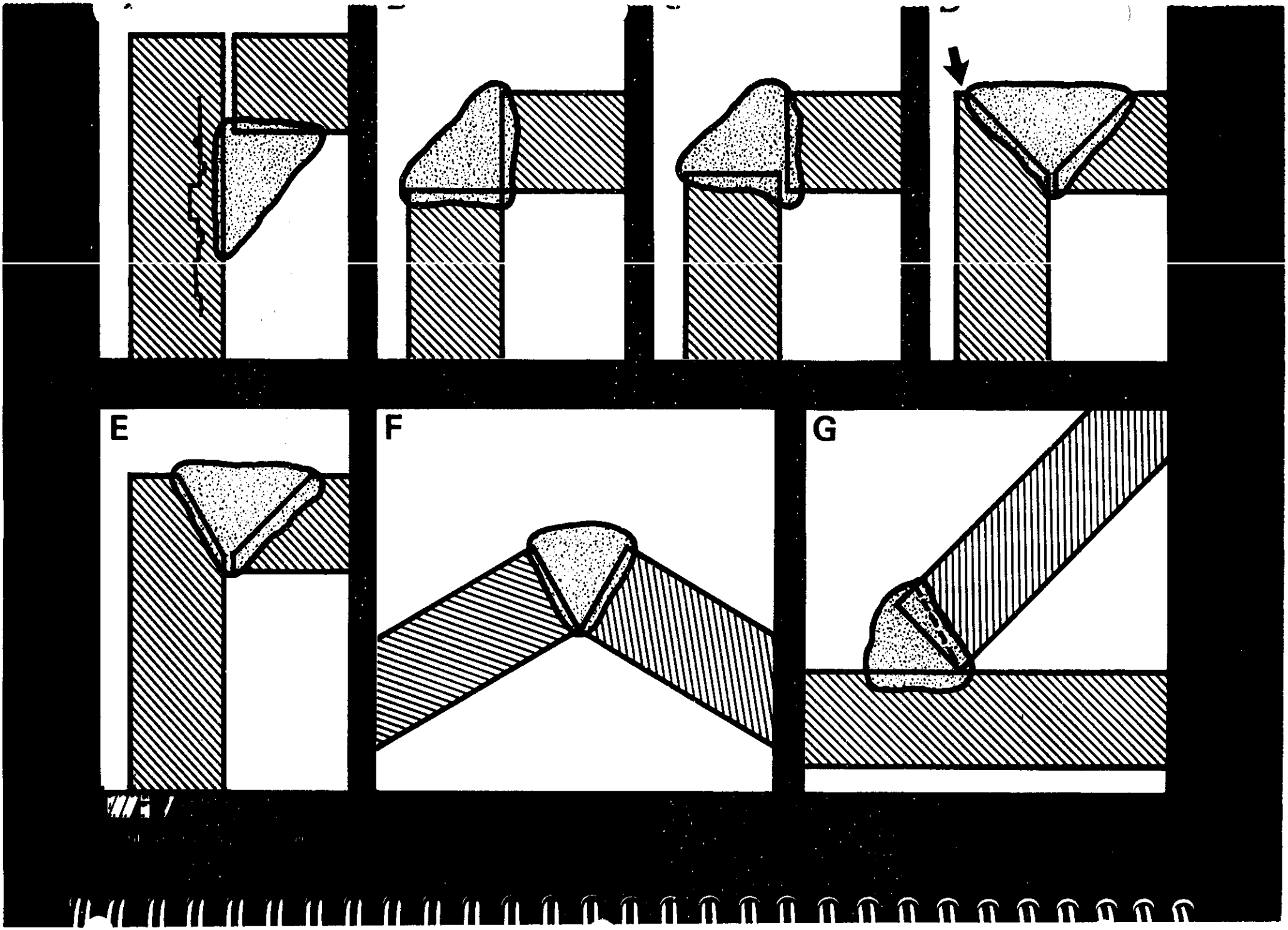
Section shown on		Left	Right
Parent metal thickness		25	8-25
Position		Flat	H-V
Process		MMA	MMA Cellulosic
Root face	A	2	1.5
Angle of bevel	B	20	-
Upper		-	45
Lower		-	15
Gap	G	2	1.5
Included angle	I	20	60
Land	L	0	-
Root radius	R	10	-
* 'Standard data . . .'table		-	13
* 'Joint preps....' page		16	-

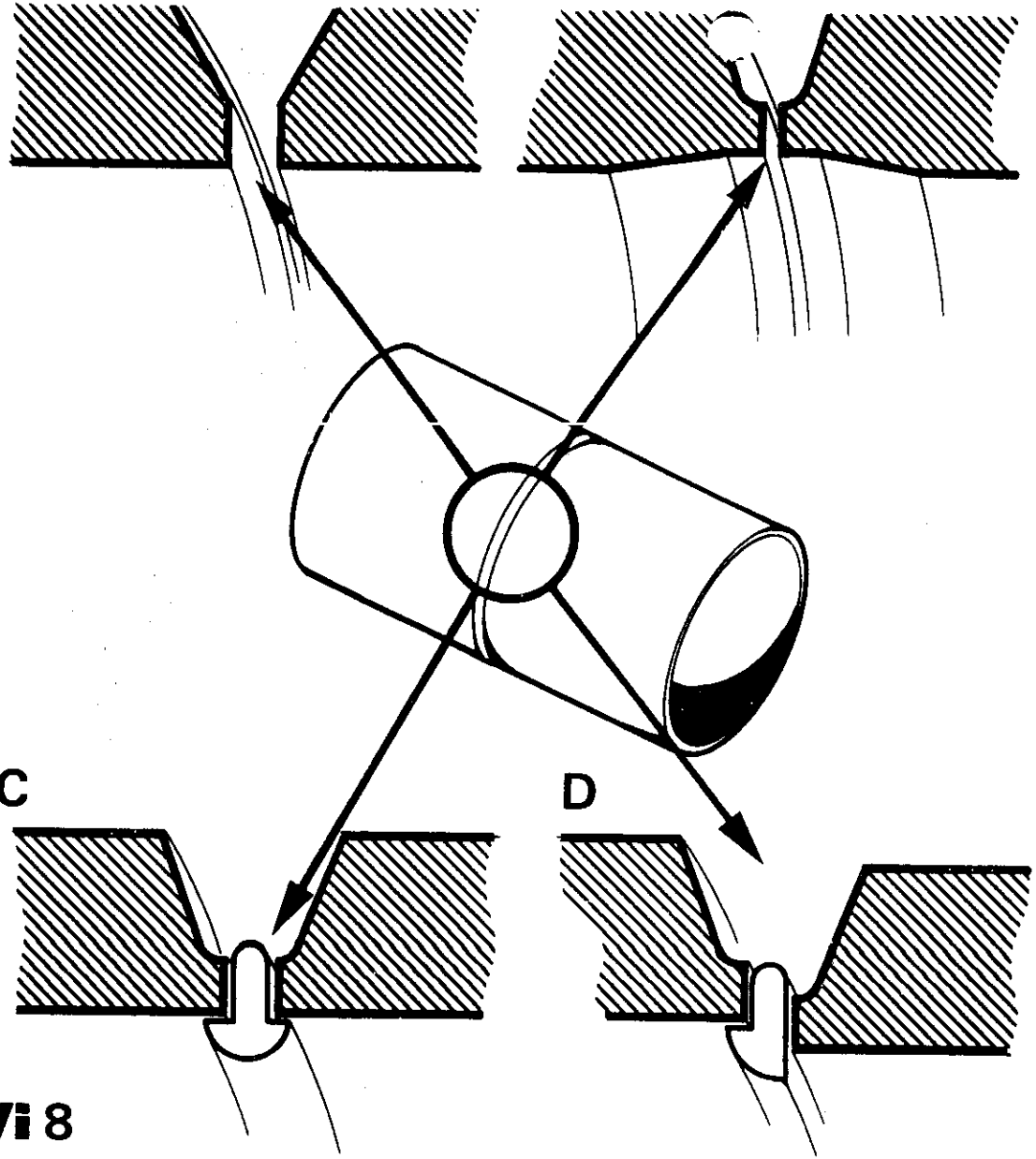
* location of data in WI publications referred to in the introduction (1975/1976 editions).

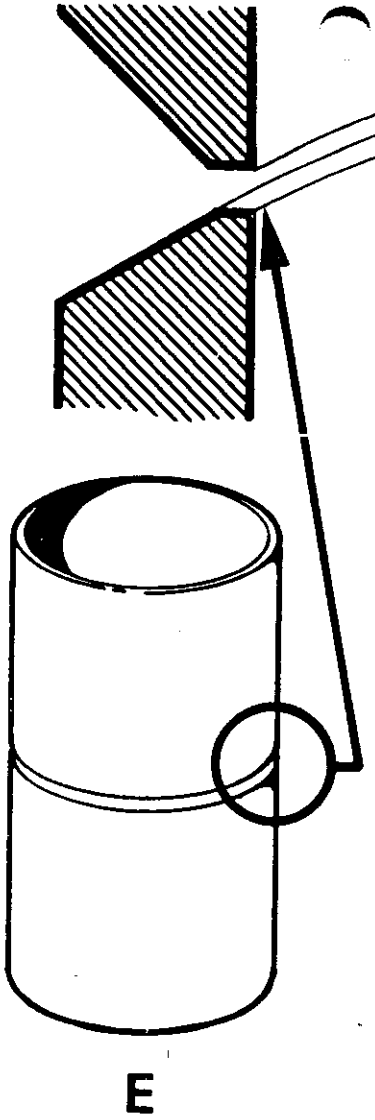
Remedial action

Problem	Gap	Root face	Angle of bevel	Welding current
	(I-Increase : D-Decrease)			
Insufficient penetration	I	D	-	I
Excess penetration	D	I	-	D
Lack of fusion Slag inclusions (where due to restricted access)	I	D	I	I
Excess distortion	D	-	D	I
Slow welding	D	I	D	I

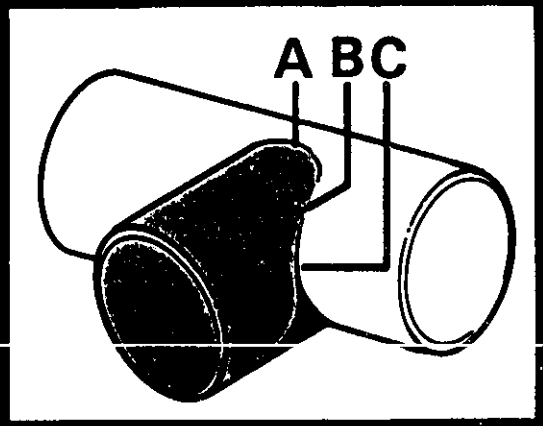


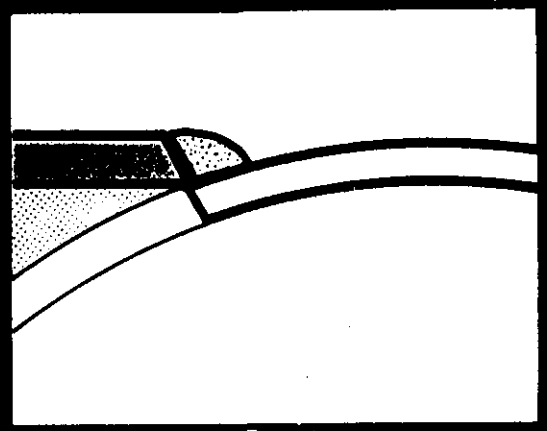

E
F
G

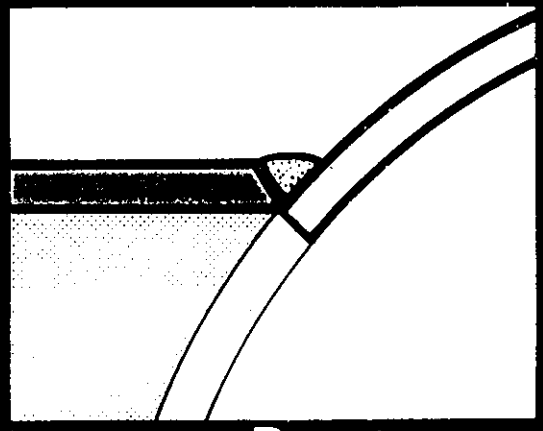


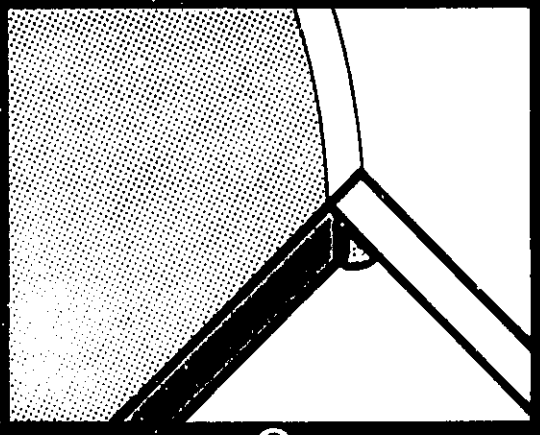


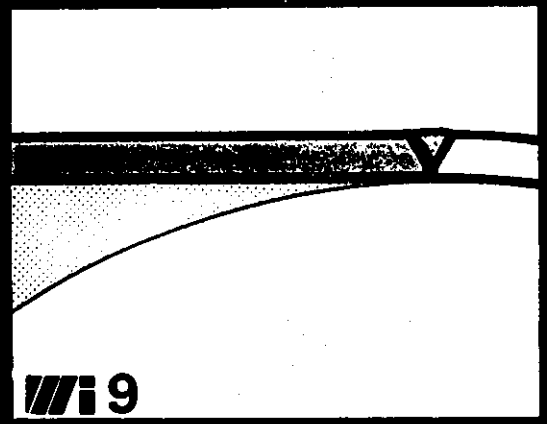
Wi 8

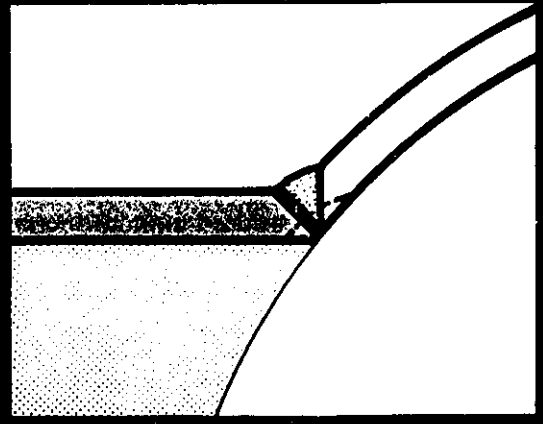


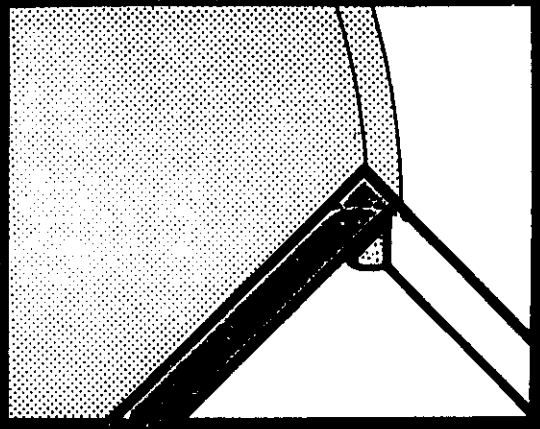

A

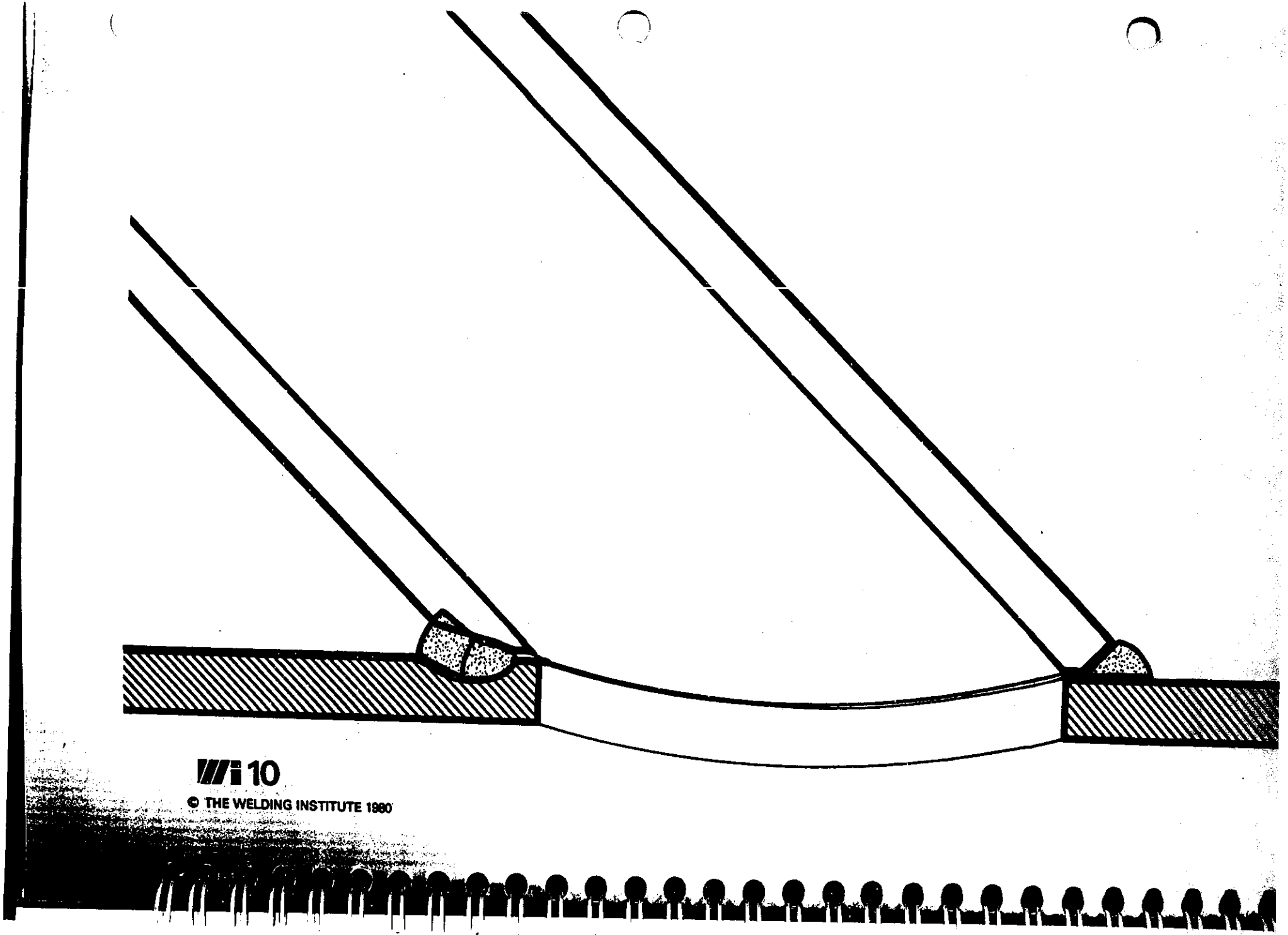

B

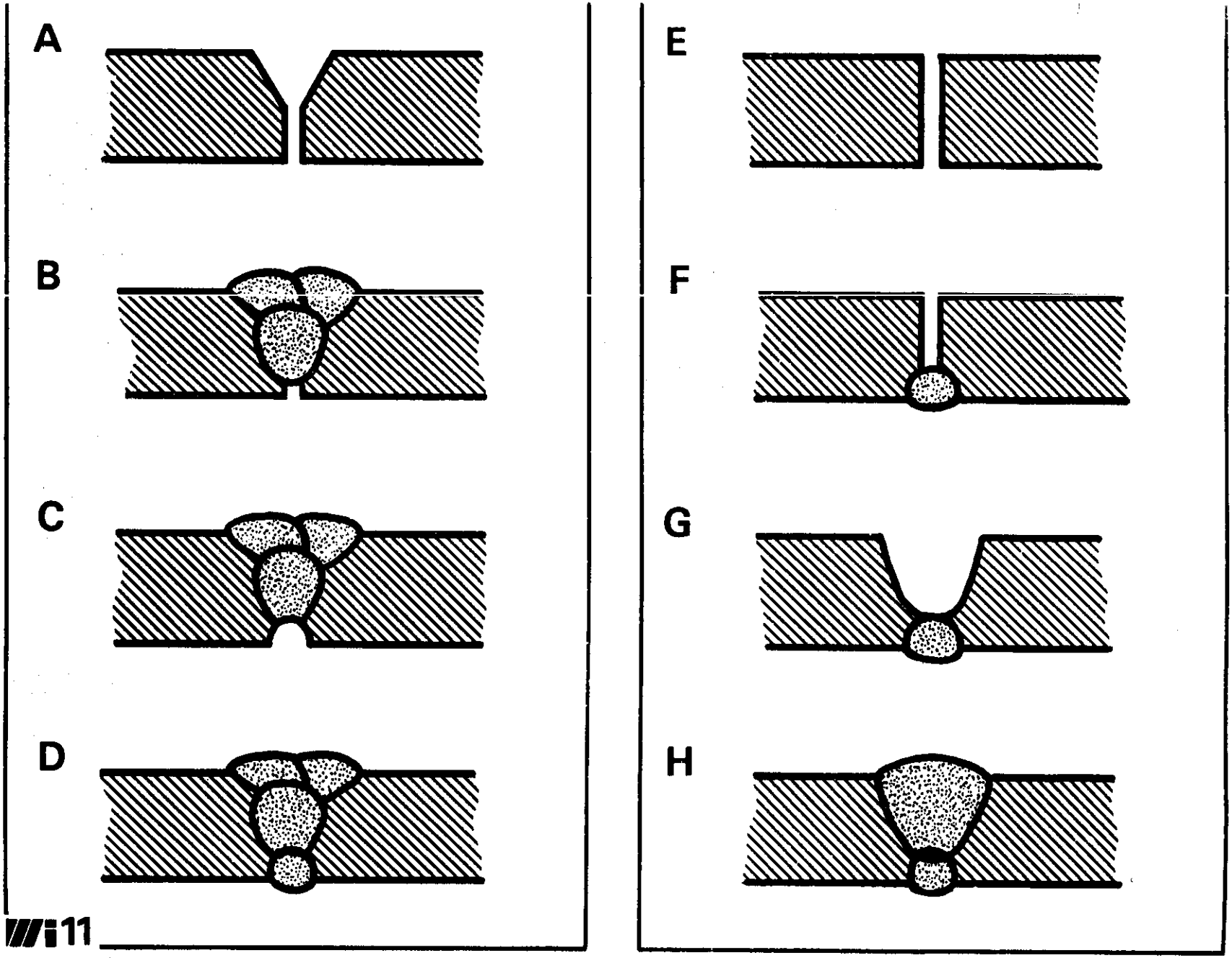

C



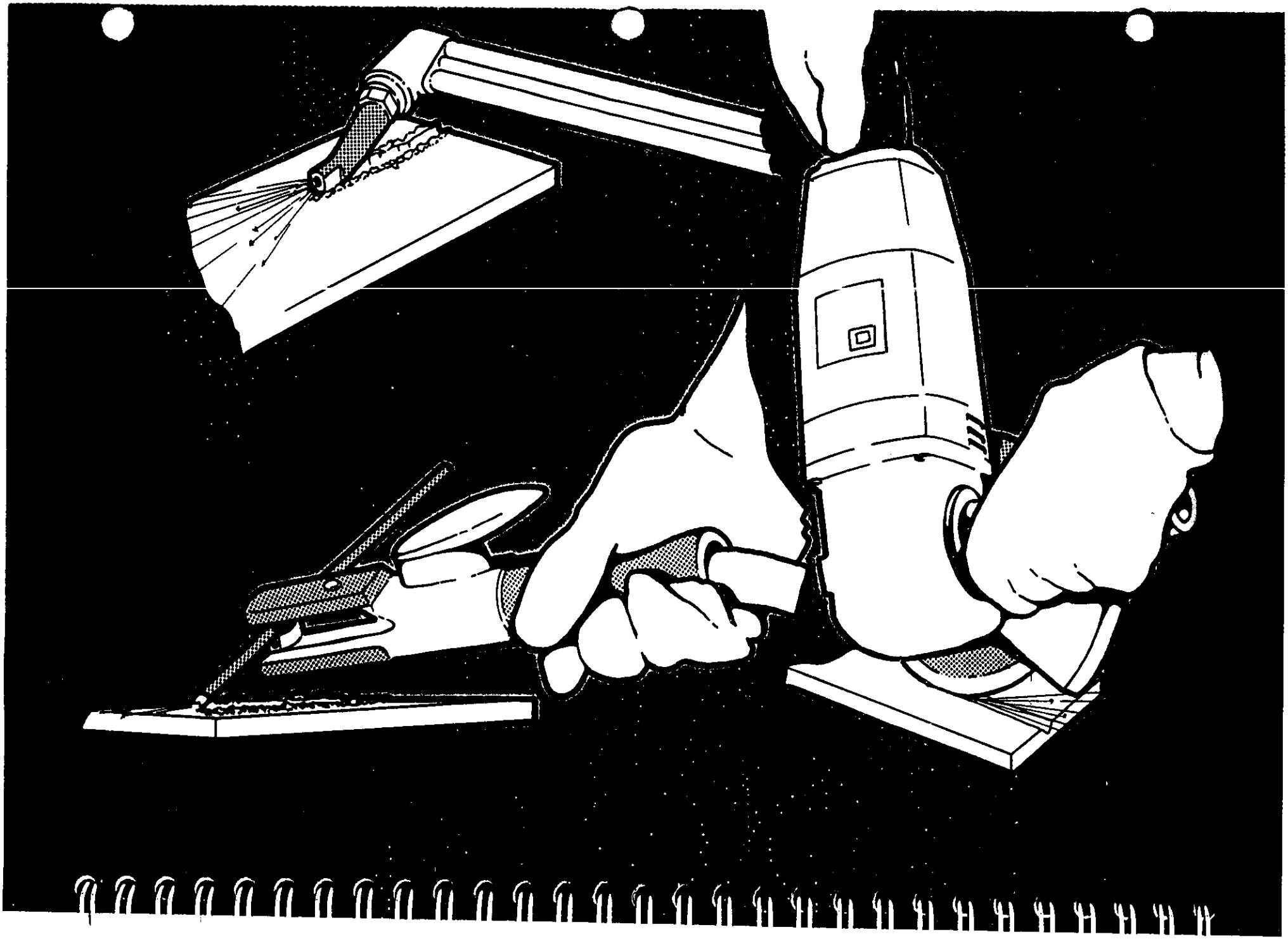


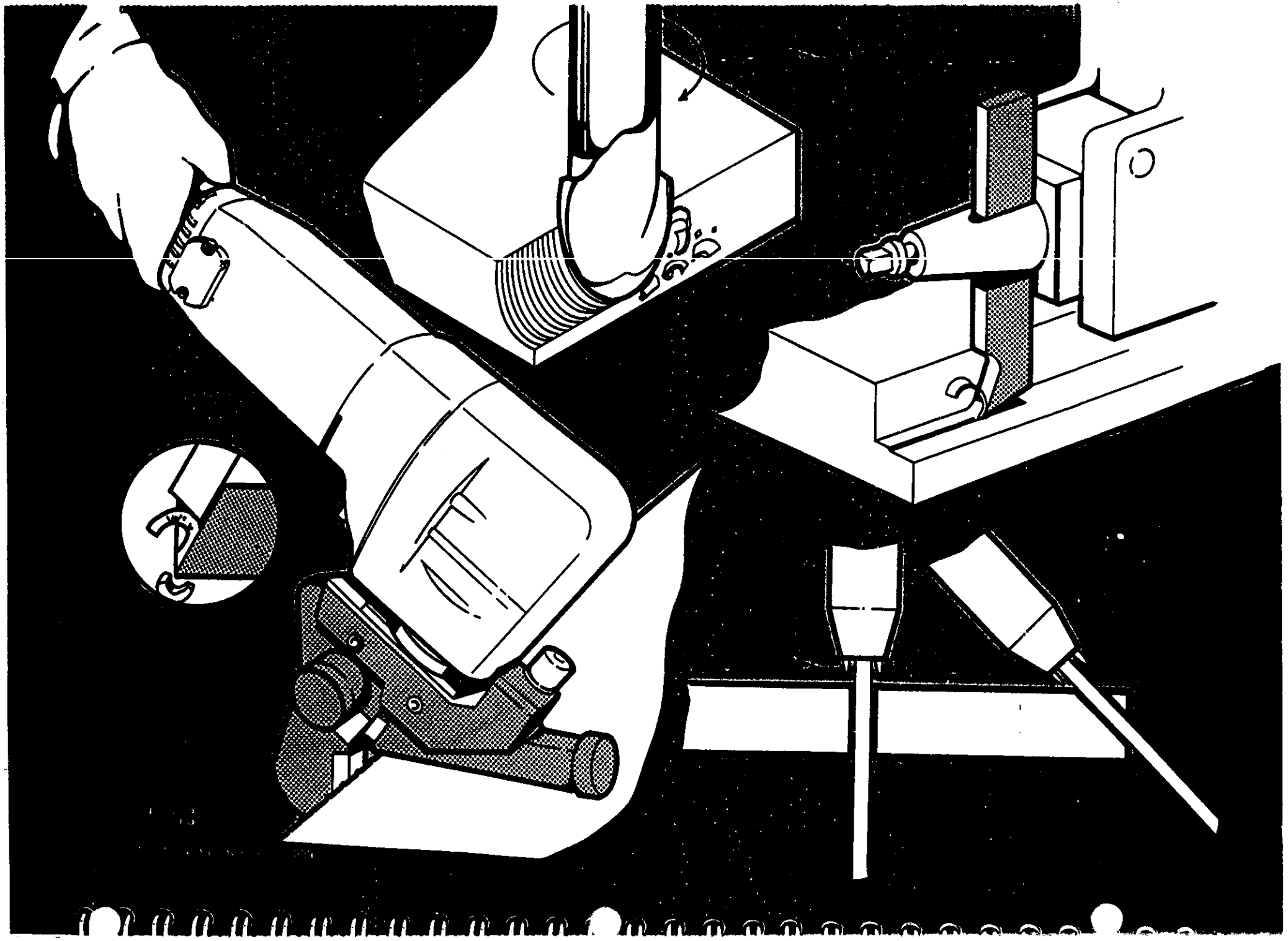


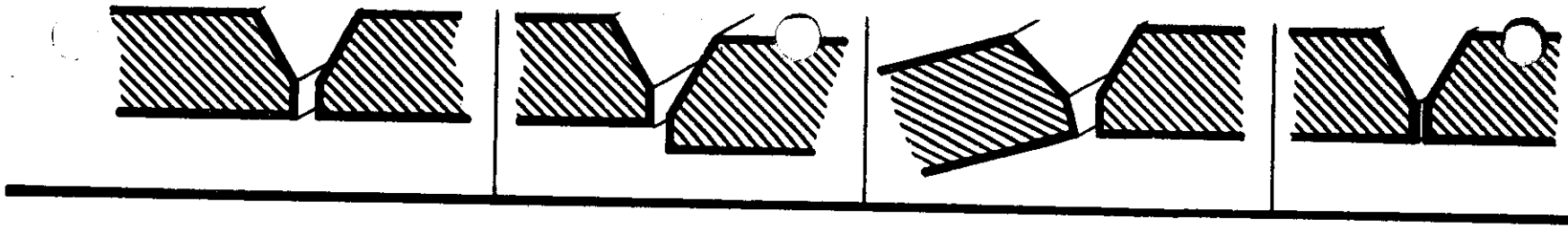


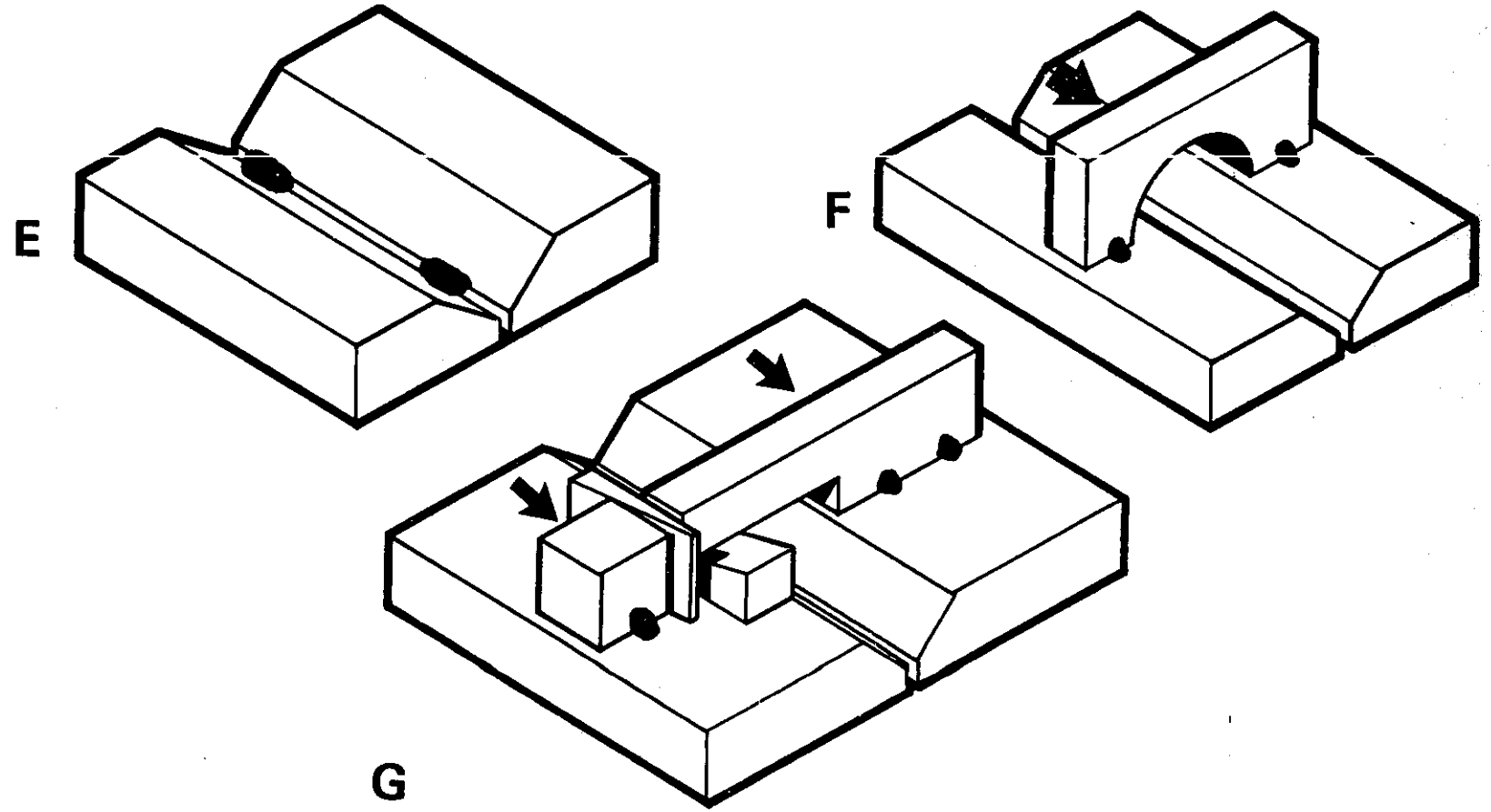


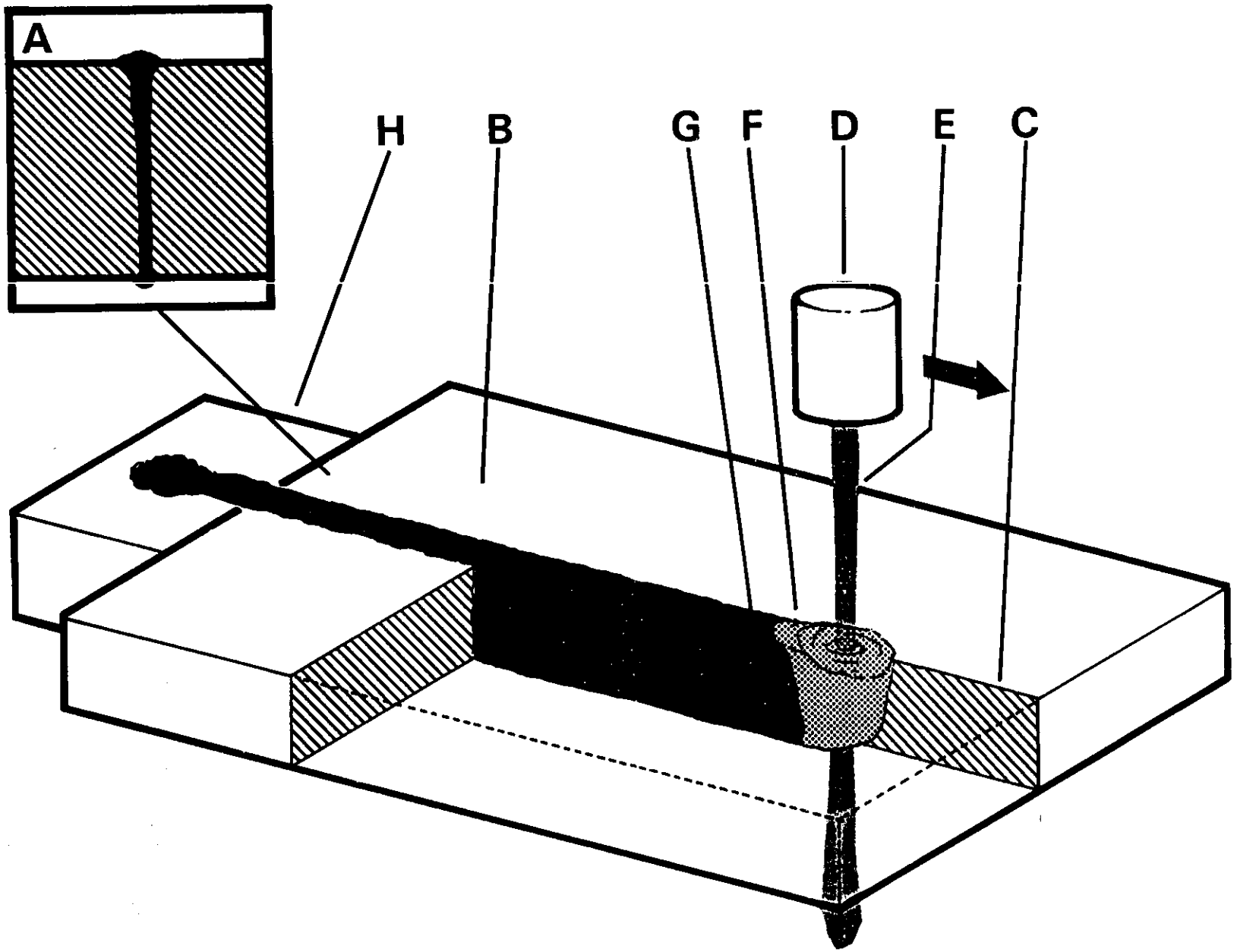
i11











Wi 15